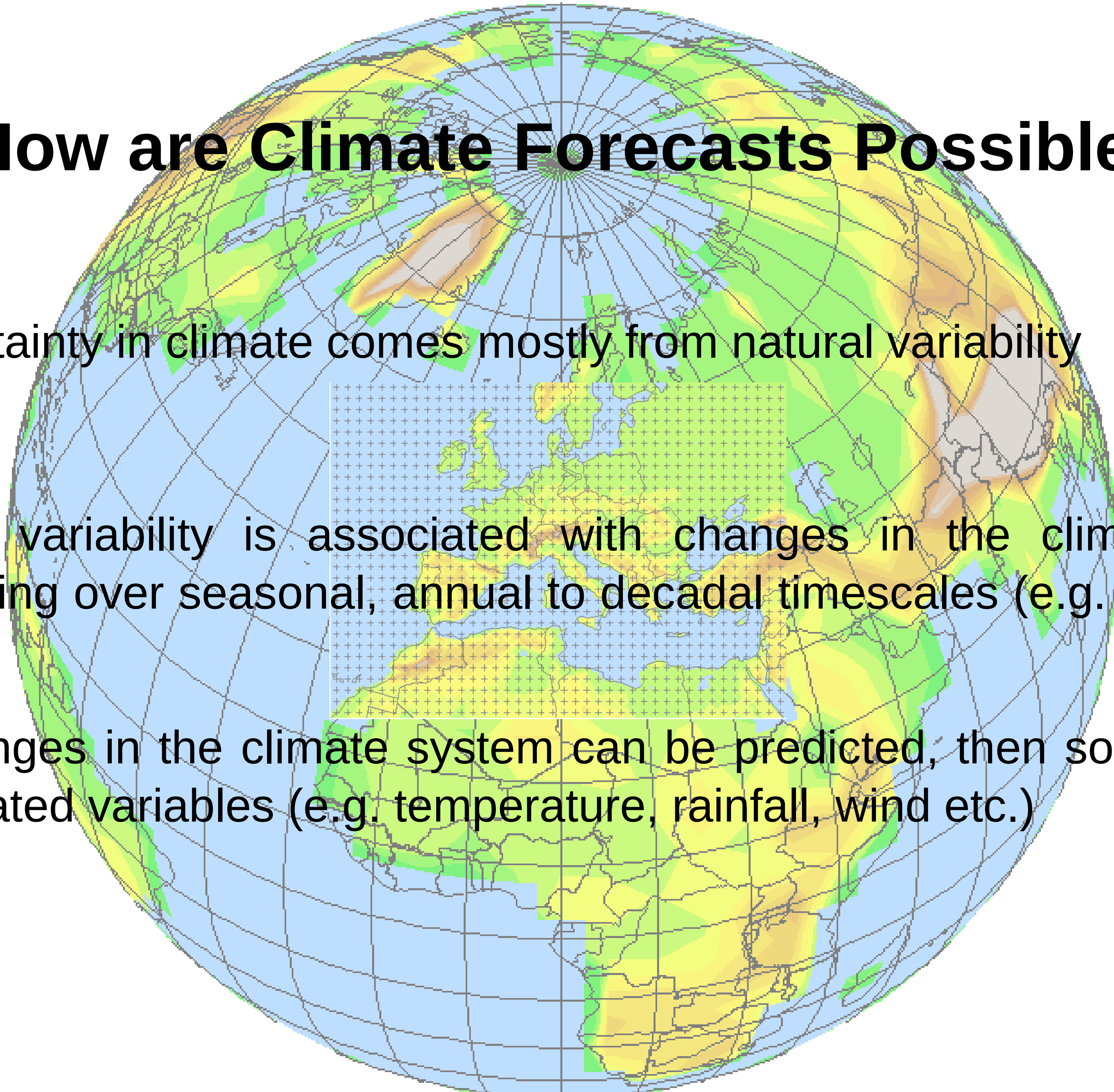
How are Climate Forecasts Possible?



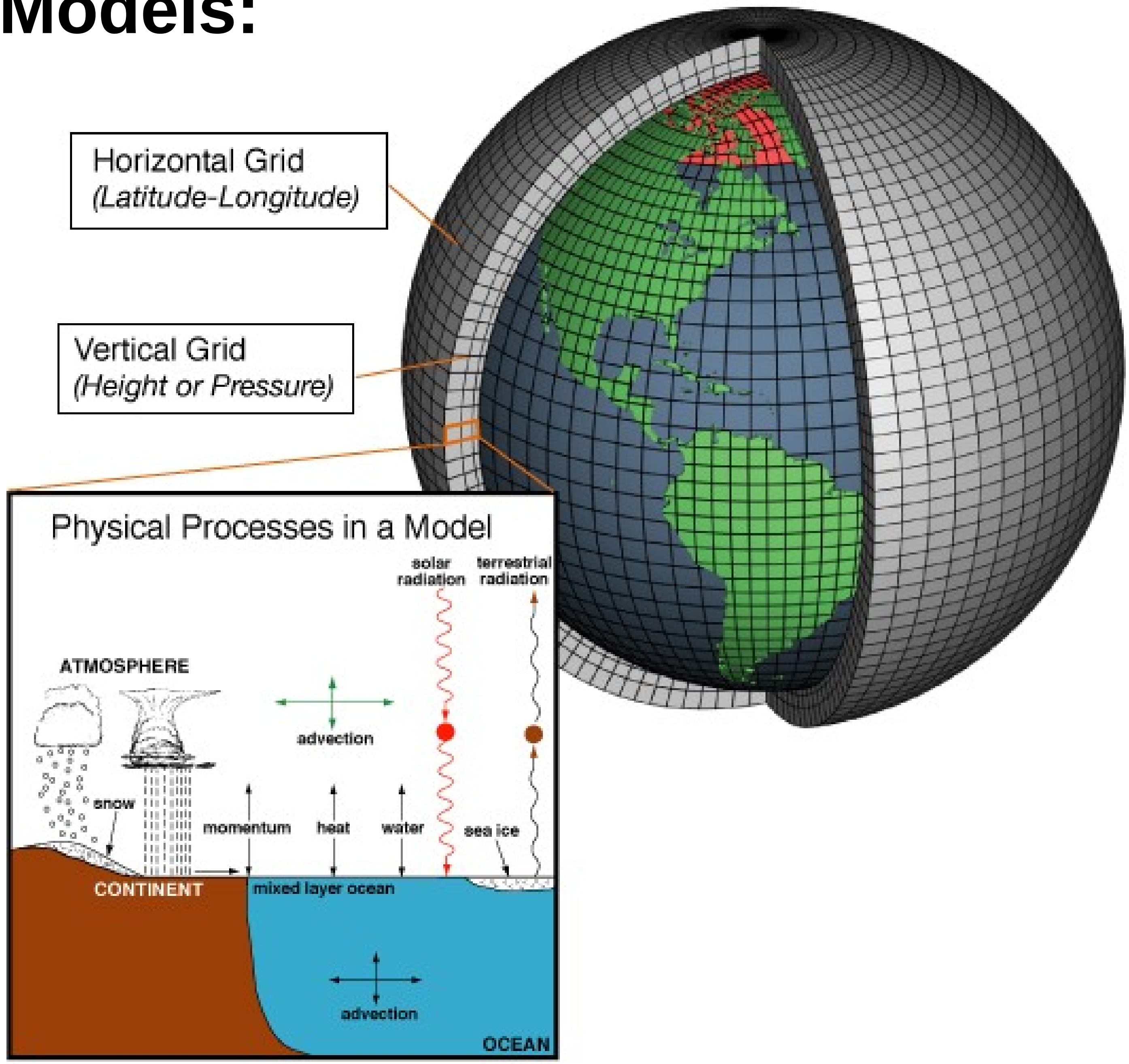
- Uncertainty in climate comes mostly from natural variability
- Some variability is associated with changes in the climate system occurring over seasonal, annual to decadal timescales (e.g. NAO, AMO)
- If changes in the climate system can be predicted, then so could other correlated variables (e.g. temperature, rainfall, wind etc.)

Changes in the Climate System

Climate Factor	Description	Timescales
Atlantic Multidecadal Oscillation (AMO or AMV)	Oscillation in North Atlantic Ocean Temp.	Decada l
El Niño Southern Oscillation (ENSO)	Oscillation in Tropical Pacific Ocean Temp.	Multi-annual (3-5 yr cycle)
North Atlantic Oscilllation (NAO)	See-saw of sea level pressures b/w Iceland and the Azores	Annual
Dust/Aerosols over Atlantic	Dust originating from Sahara Desert	Annual
West African Monsoon	Rainfall over Sahel region	Annual
Maidden-Julian Oscillation	Eastward Propagating Disturbances in Tropics	Intra-Seasonal

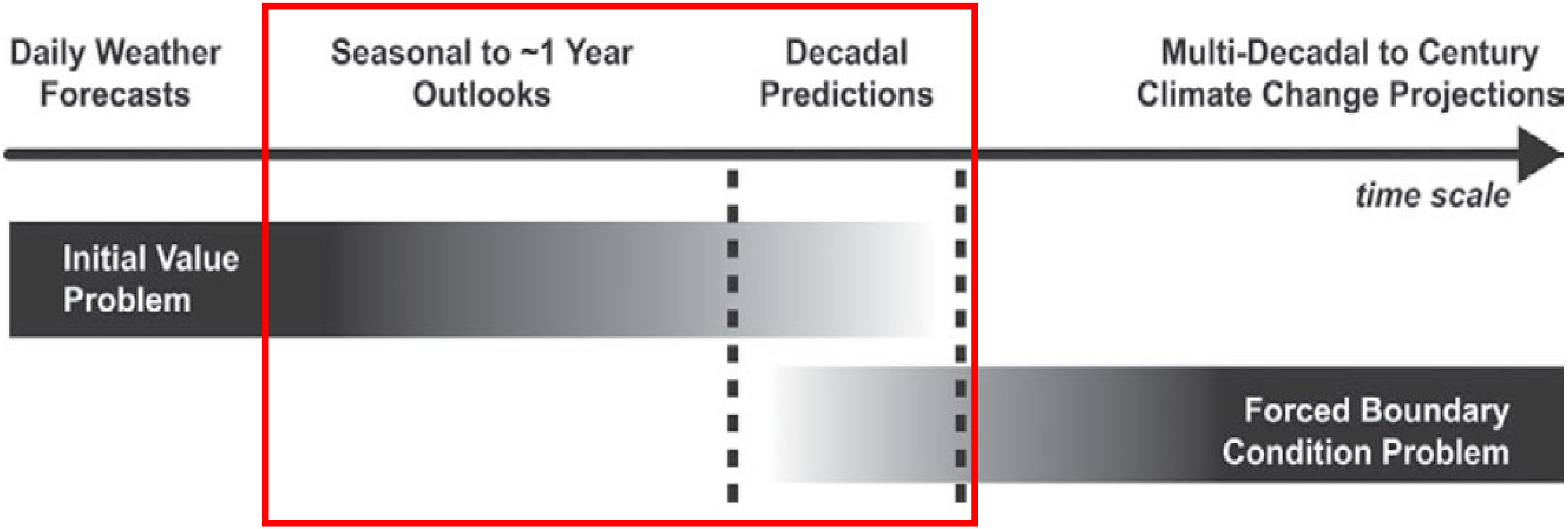
Global Climate Models:

Simulating the Climate System



Climate Time Scales

- Initial-value problems (weather forecasting) to forced boundary condition problem (climate projections)
- Climate forecasts (sub-seasonal, seasonal and decadal) in the middle



Meehl et al. (2009)

Climate Forecasts:
State-Of-The-Art Approach

Stage 1: Dynamical forecasts

- Initialisation of ensemble simulations

Stage 2: Post-processing

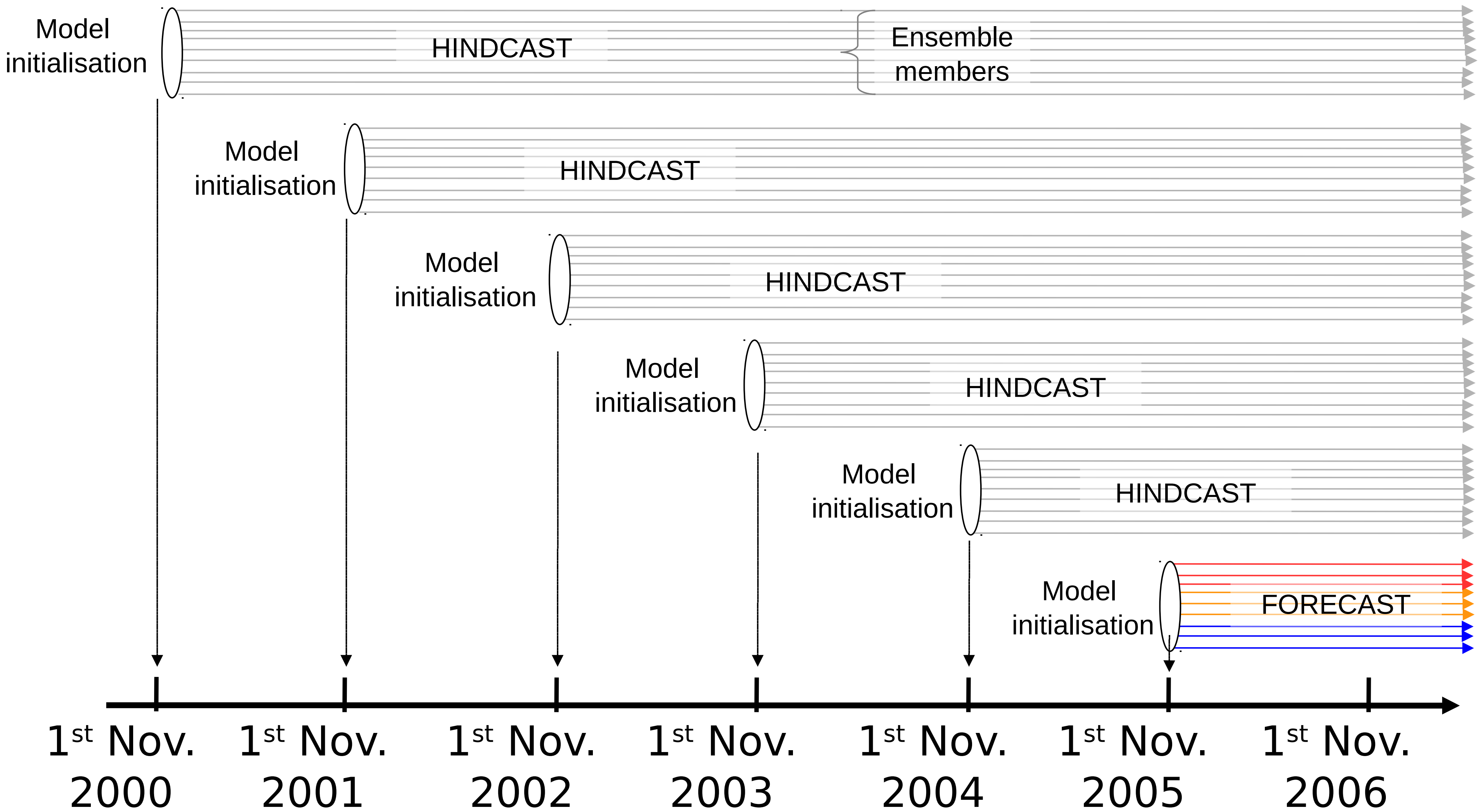
- Bias correction or calibration
- Combination: multi-model approach

Stage 3: Validation

- Verification: skill assessments

Stage 1: Dynamical forecasts

Initialisation of ensemble simulations



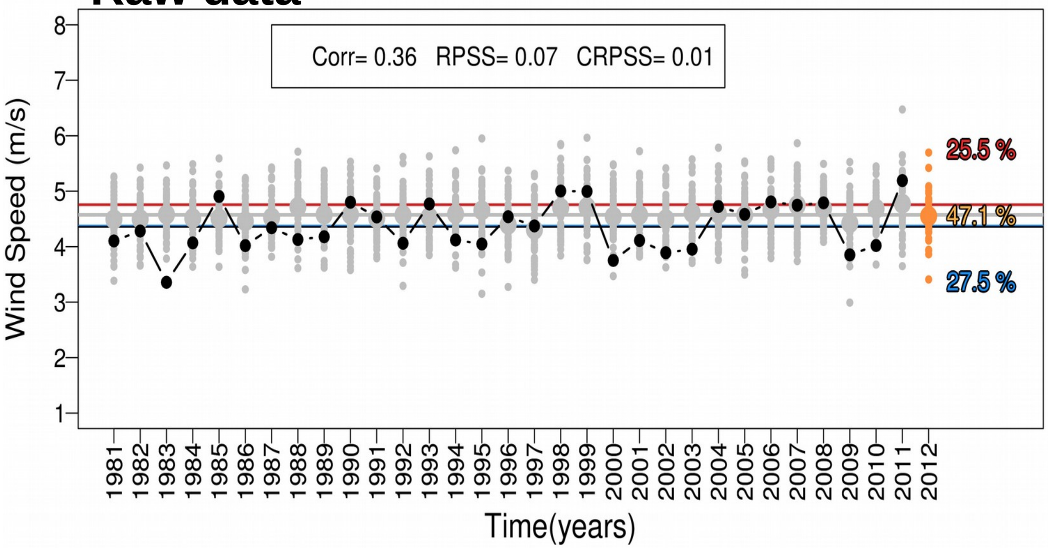
Start date November 1st each year over past 30 year period

1 experiment: 120Tb

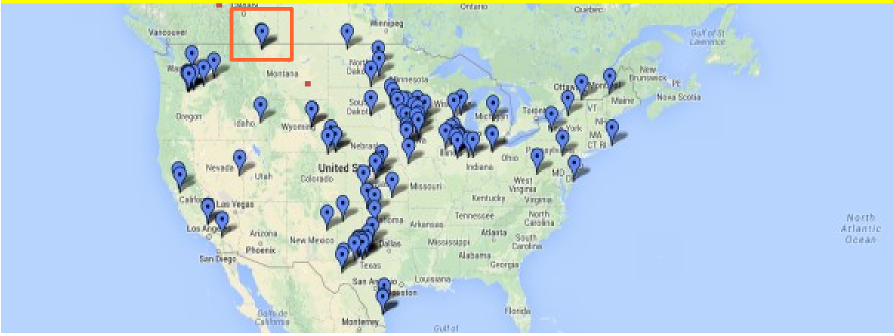
Stage 2: Post-processing

Bias correction or calibration

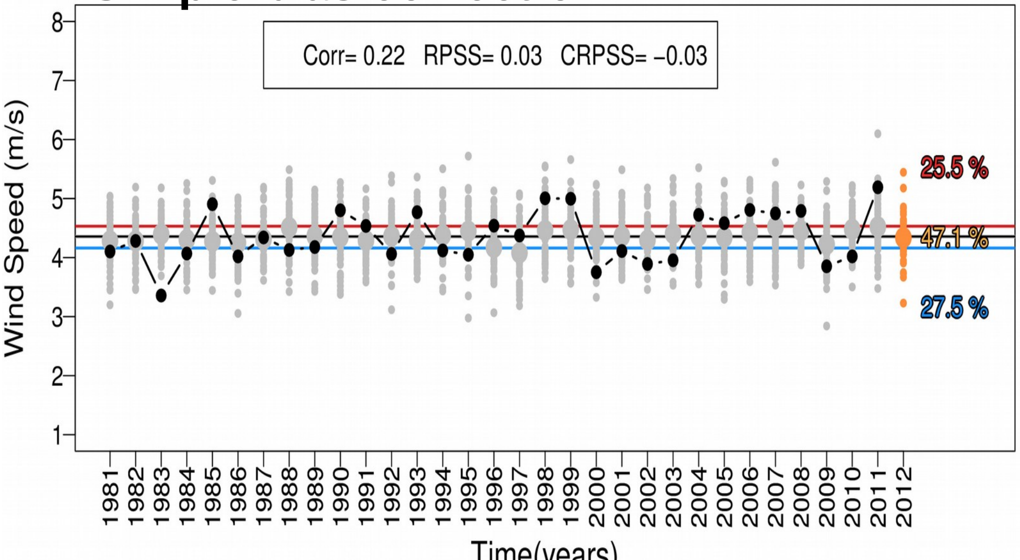
Raw data



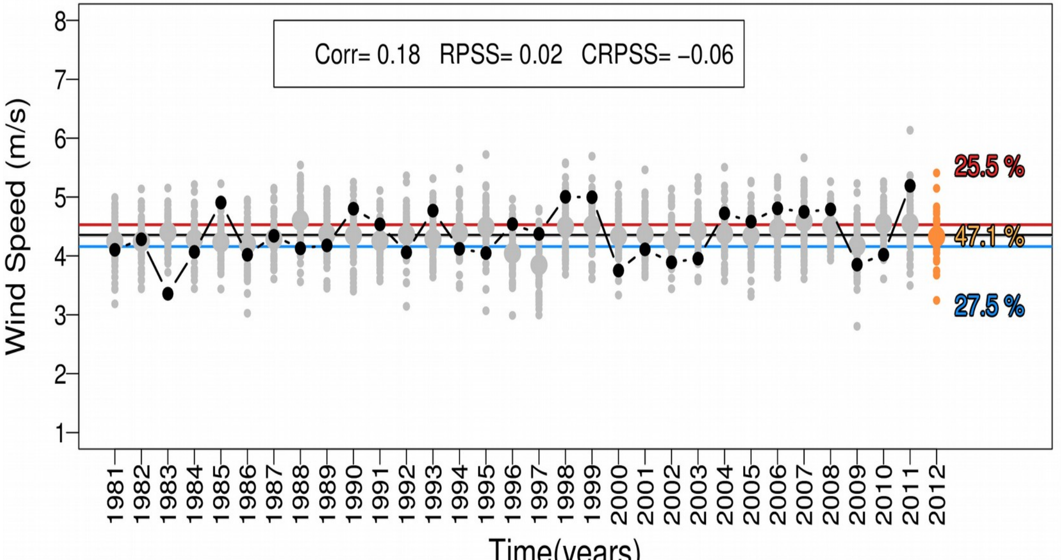
Climate model:ECMWF S4
10m wind speed “observations”: ERA-Interim
Winter season forecast: 1 month lead time



Simple bias correction

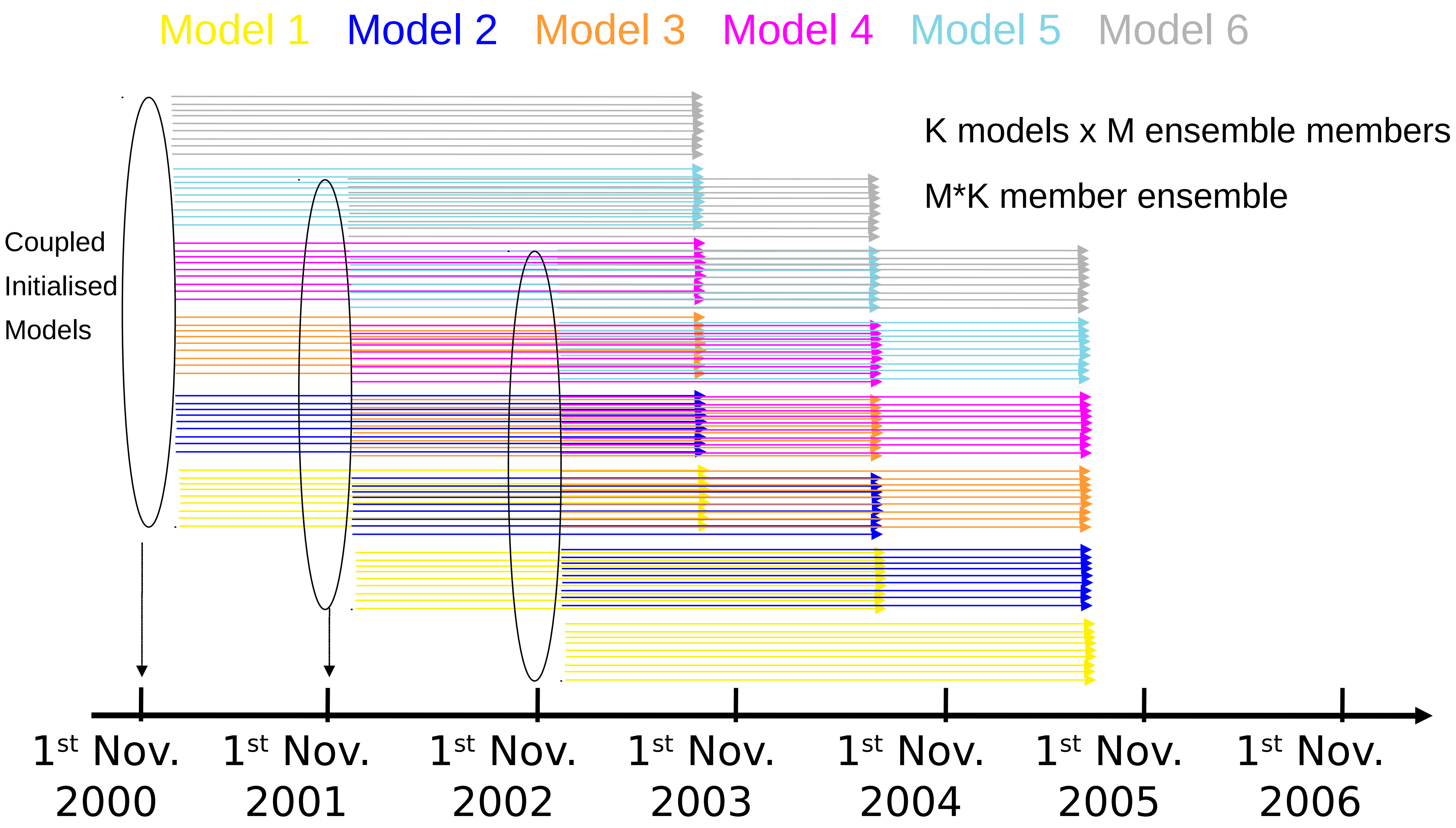


Calibration



Stage 2: Post-processing

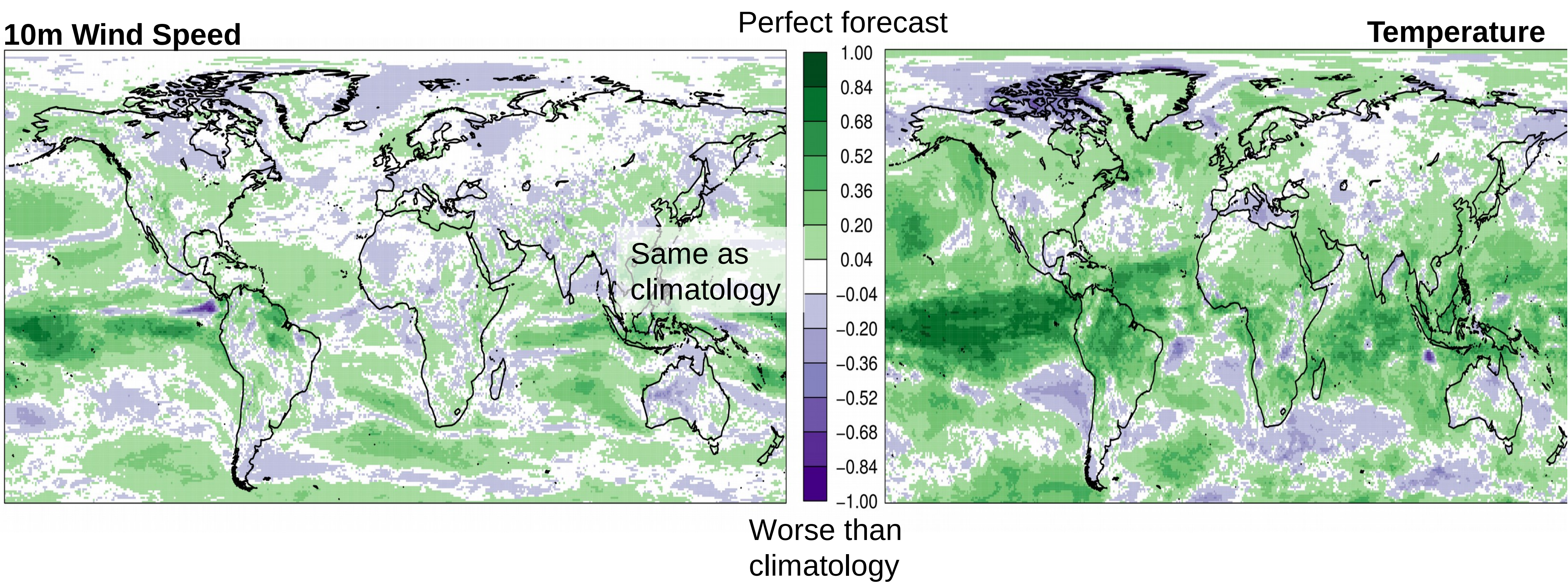
Combination: multi-model approach



Stage 3: Validation

Verification: skill assessments

Climate model:ECMWF S4
“Observations”: ERA-Interim, past 30 years
Winter season forecast: 1 month lead time



FURTHER VALIDATION POSSIBLE BASED ON REAL MEASUREMENTS

Climate Services based on Climate Forecasts

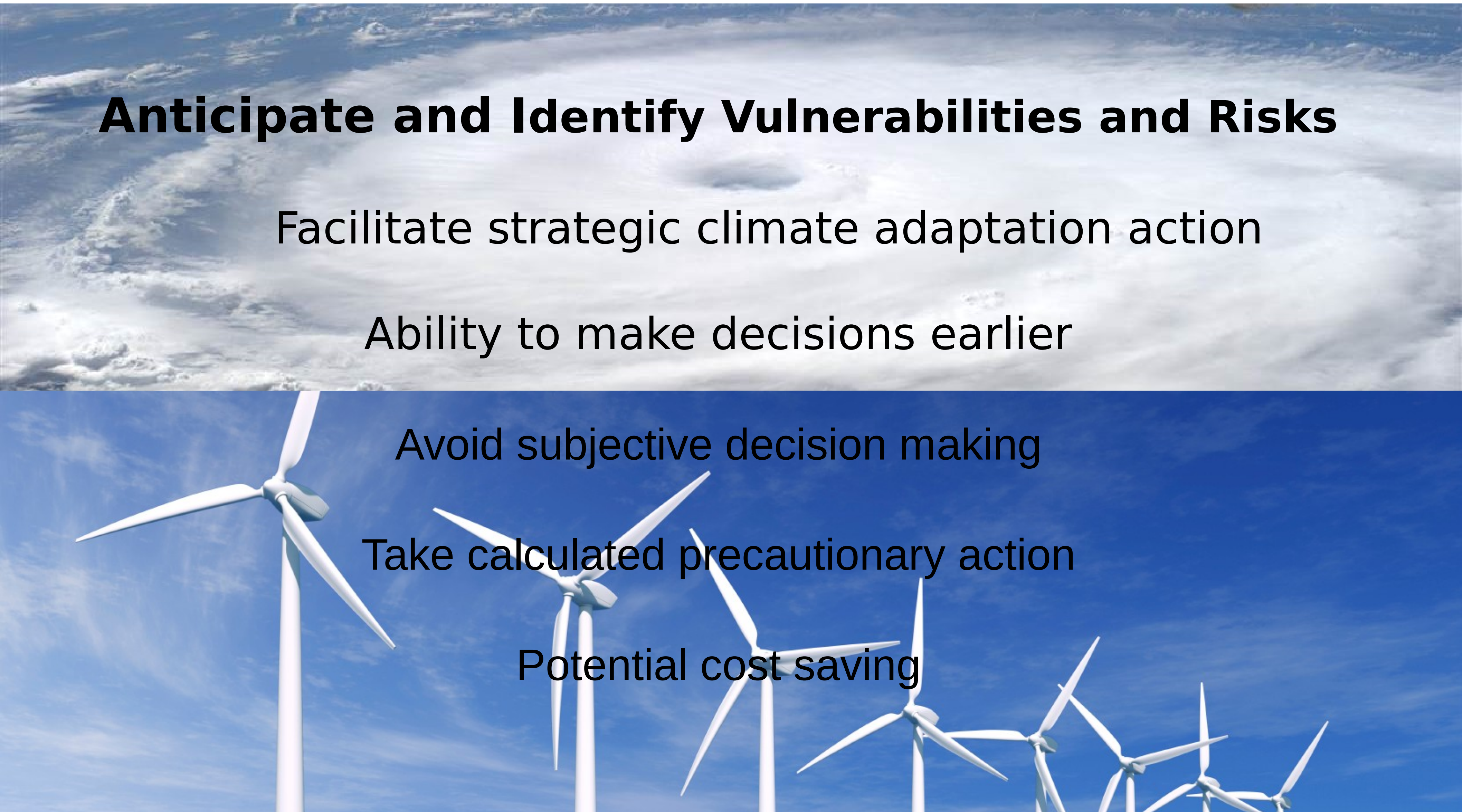
Example 1: Risk Prediction Initiative for Insurance/Re-insurance

- Tropical Cyclones: Decadal Forecasts

Example 2: EU Projects involving EDF and Vortex

- Wind Power: Monthly and Seasonal Forecasts

WHY?


Anticipate and Identify Vulnerabilities and Risks
Facilitate strategic climate adaptation action
Ability to make decisions earlier
Avoid subjective decision making
Take calculated precautionary action
Potential cost saving

Multi-annual forecasts of Atlantic tropical cyclones

Objective: Evaluate the capability to forecast Atlantic Tropical Cyclone activity over a 5-year horizon

Louis-Philippe Caron, IC3

Climate factors influencing Atlantic Cyclone activity

Climate Factor	Description	Timescales
Atlantic Multidecadal Oscillation (AMO or AMV)	Oscillation in North Atlantic Ocean Temp.	Decada l
El Niño Southern Oscillation (ENSO)	Oscillation in Tropical Pacific Ocean Temp.	Multi-annual (3-5 yr cycle)
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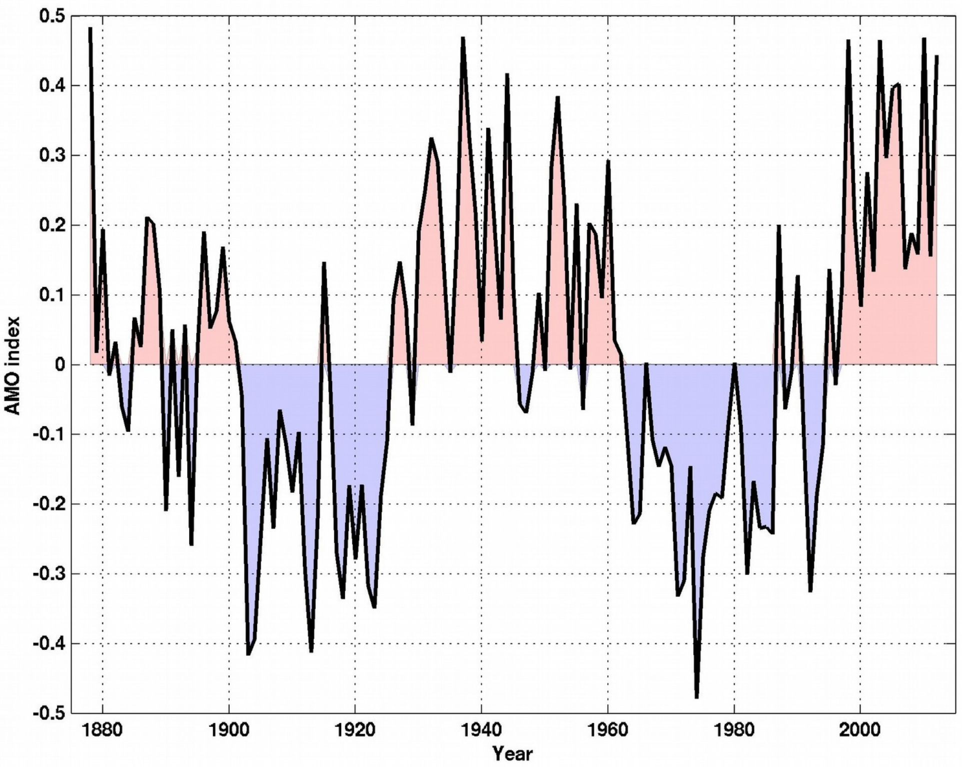
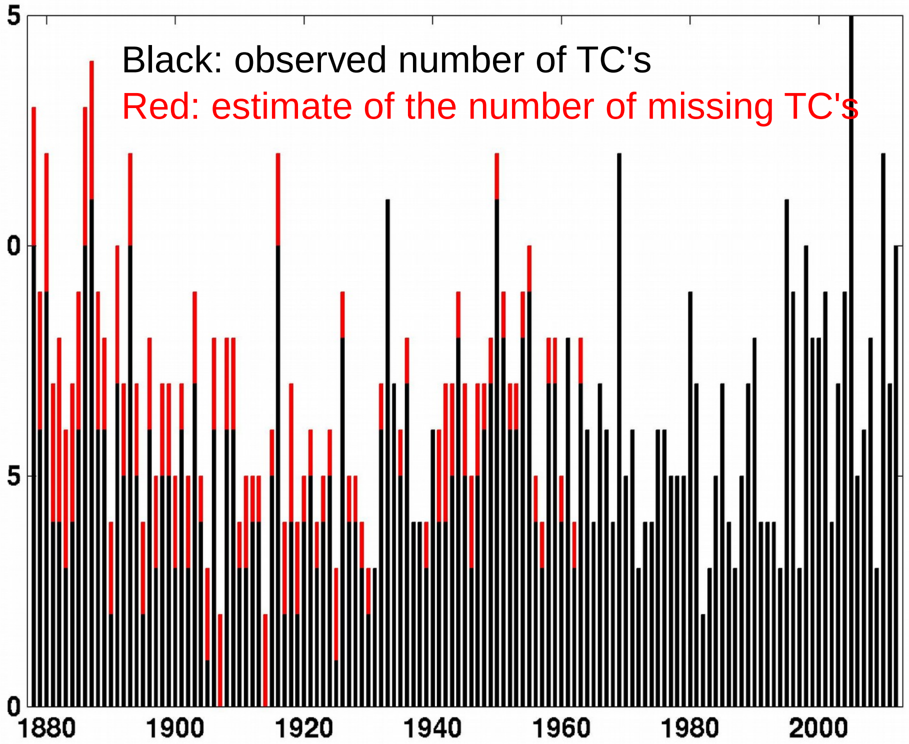
West African Monsoon	Rainfall over Sahel region	Annual
Maidden-Julian Oscillation	Eastward Propagating Disturbances in Tropics	Intra-Seasonal

Link between AMV and Tropical Cyclones (TC)

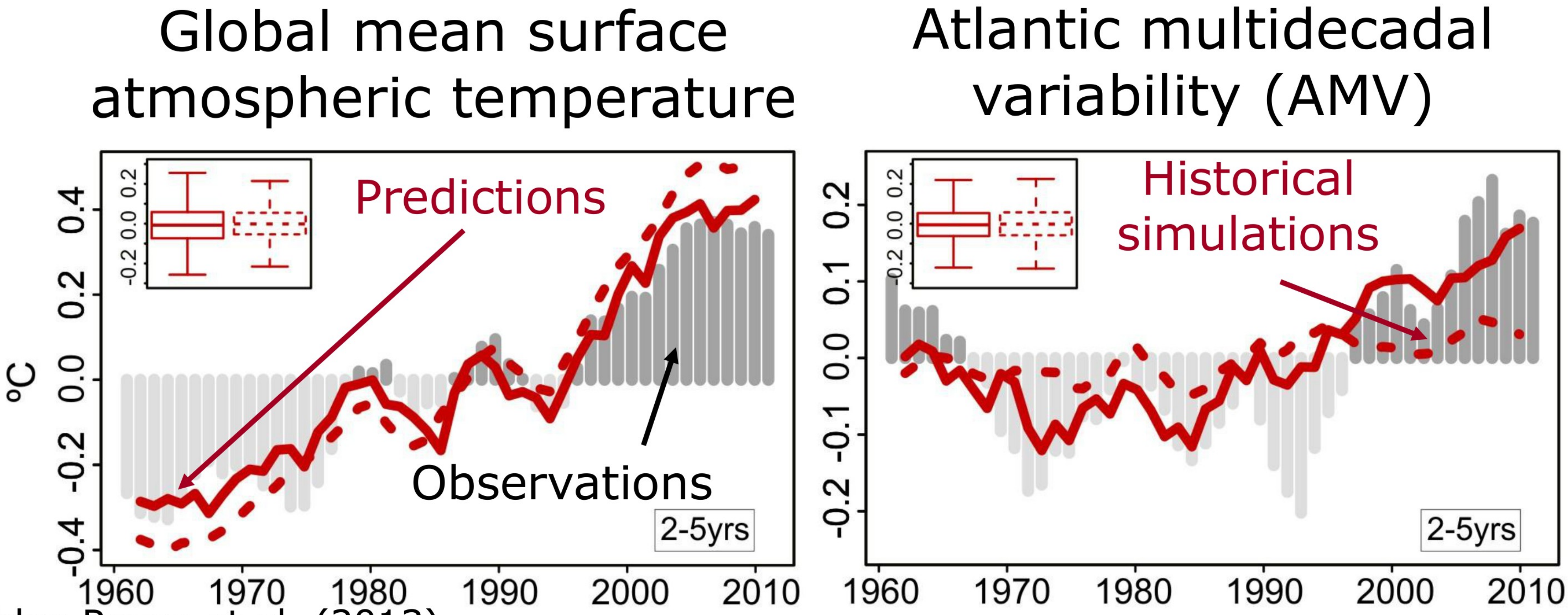


AMV: Atlantic Multidecadal Variability



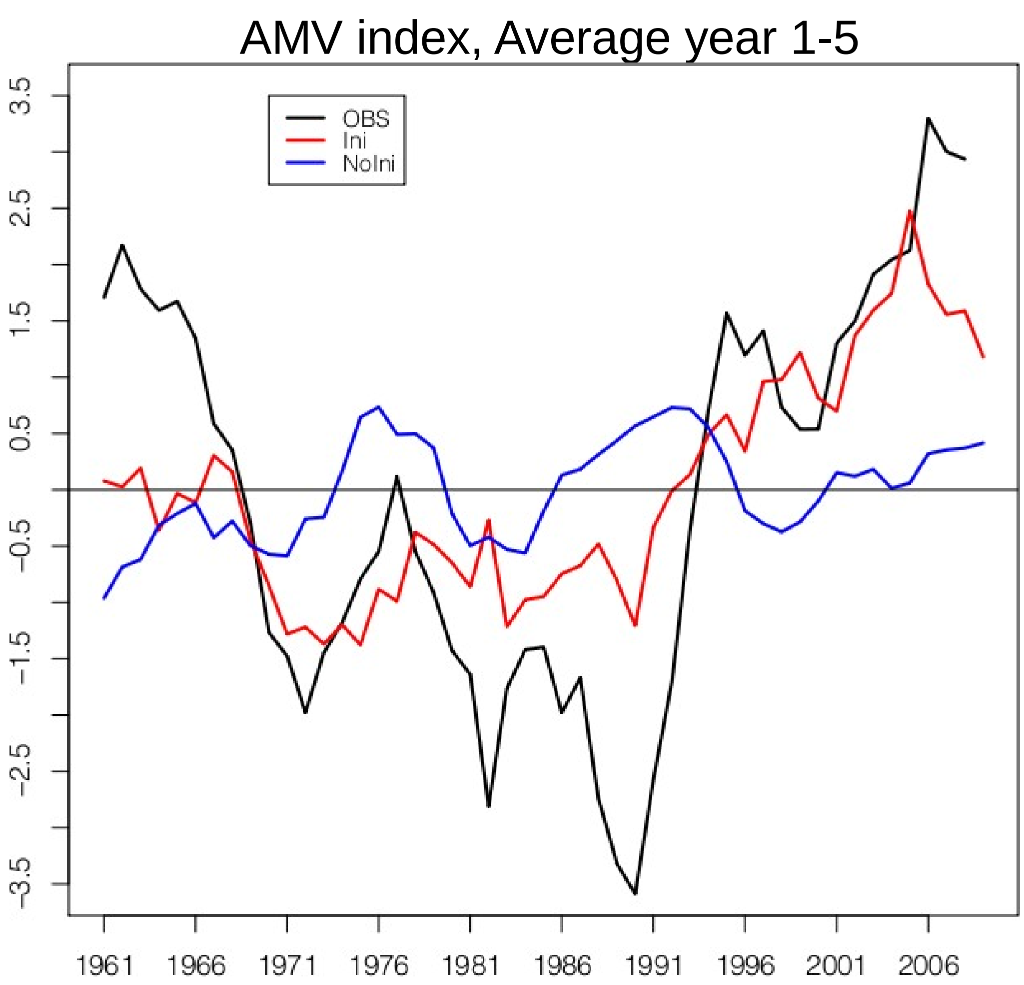
Number of Tropical Cyclones per season

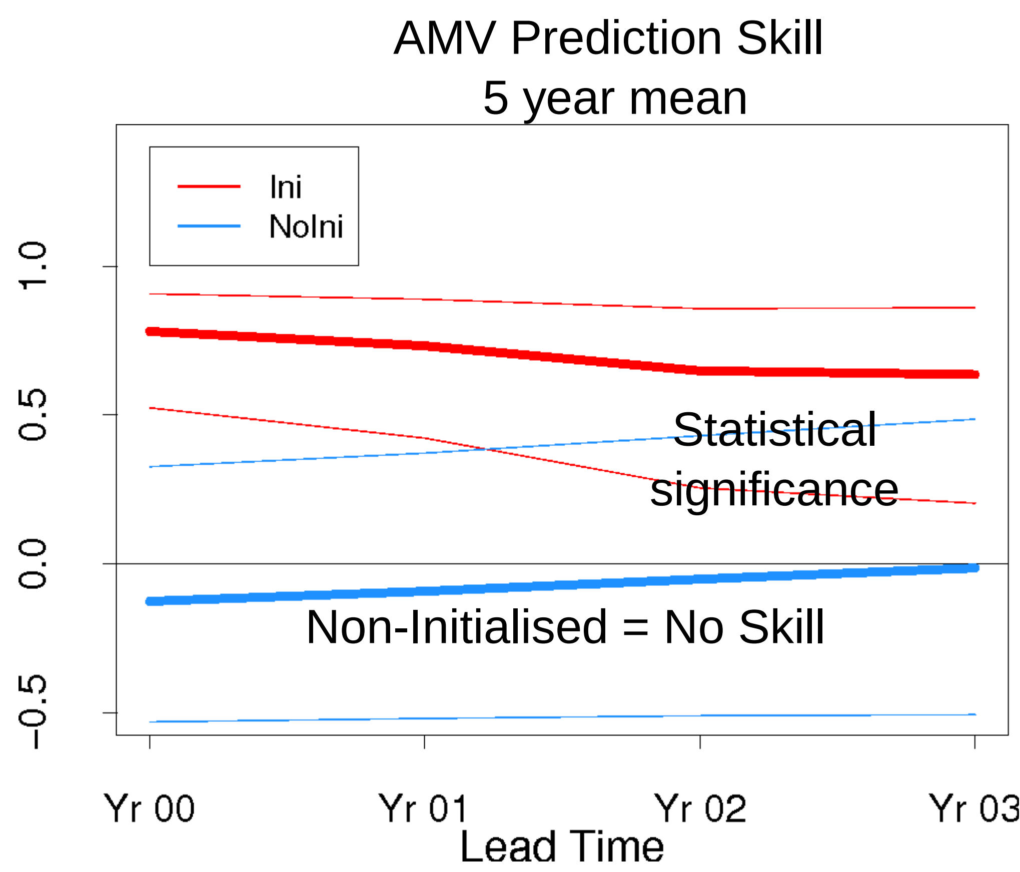
Climate Predictions v Historical Simulations



Doblas-Reyes et al. (2013)

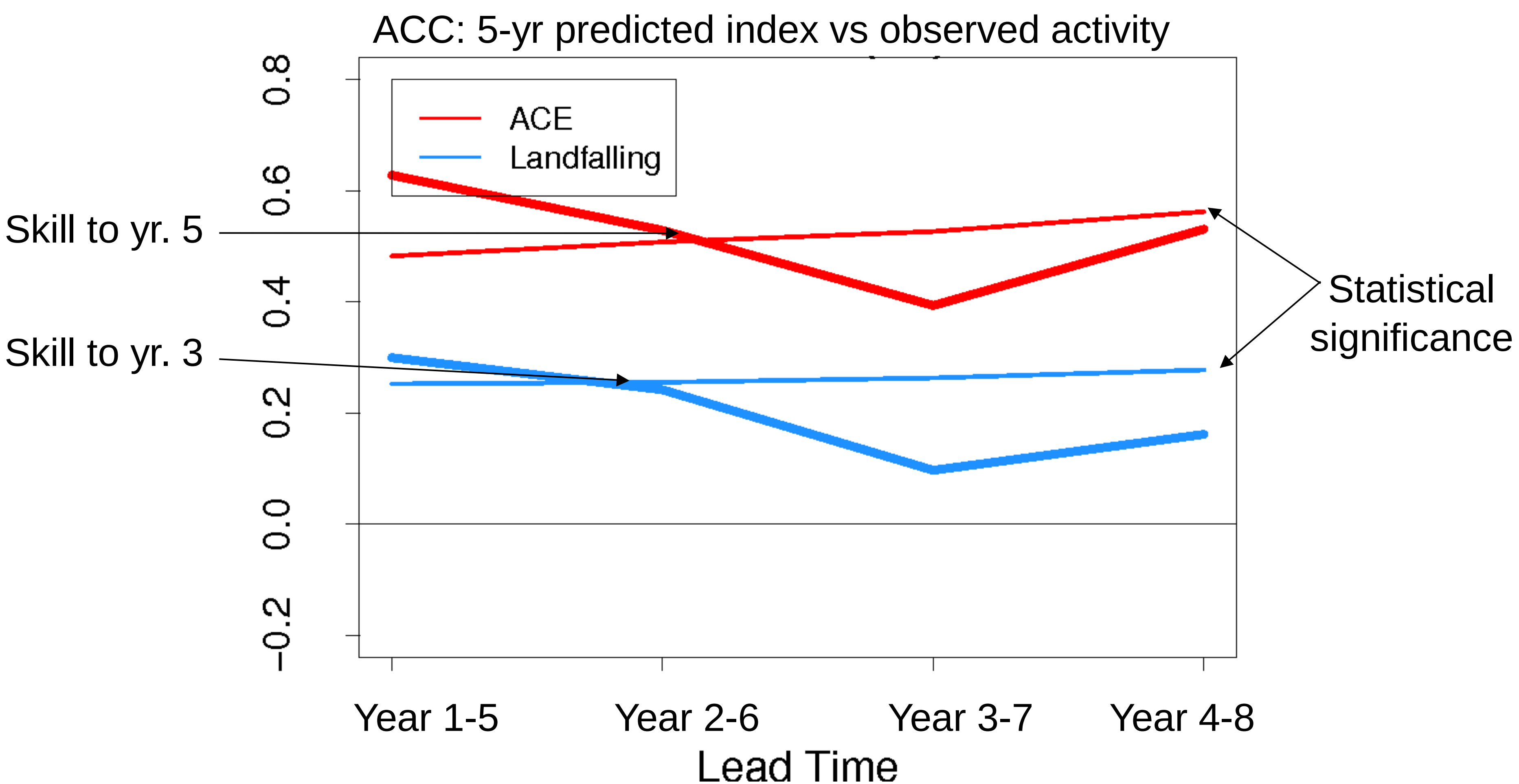
AMV Predictions: Initialised V Non-Initialised





Translating AMV Forecast Skill into TC Activity

Accumulated Cyclone Energy (ACE): Based on 6 hourly wind speed; Number, strength, and duration of all the tropical cyclones in the season.



Monthly and Seasonal Predictions of Wind Power

Objective: Evaluate the capability to predict wind power capacity over a 1-3 month horizon

Melanie Davis, Francisco Doblas-Reyes,
Verónica Torralba-Fernandez, Aido Pinto-Biescas, Nube Gonzalez-Reviriego

Monthly to Seasonal Decision Timescales

Energy producers: Resource management strategies

Energy traders: Resource effects on markets

Wind farm operators: Planning for maintenance works

Wind farm financier: Optimise return on investments

Climate factors influencing Wind Power Generation

Climate Factor	Description	Timescales
Atlantic Multidecadal Oscillation (AMO or AMV)	Oscillation in North Atlantic Ocean Temp.	Decada l
El Niño Southern Oscillation (ENSO)	Oscillation in Tropical Pacific Ocean Temp.	Multi-annual (3-5 yr cycle)
North Atlantic Oscilllation (NAO)	See-saw of sea level pressures b/w Iceland and the Azores	Annual
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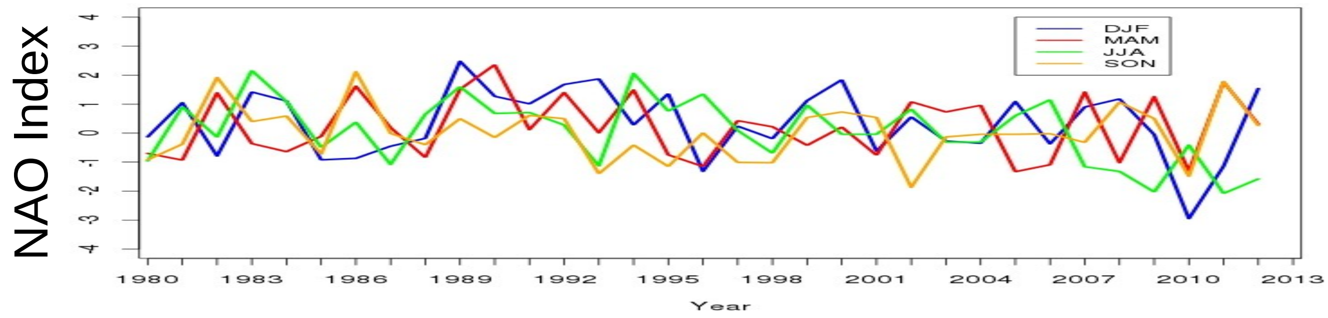
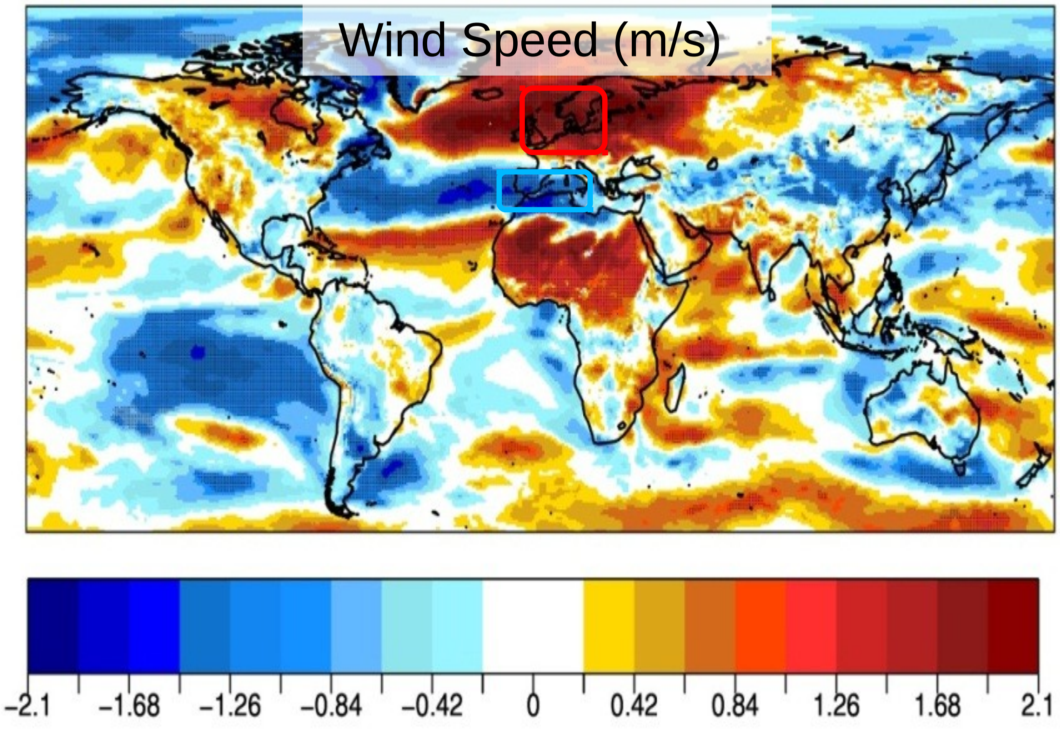
West African Monsoon	Rainfall over Sahel region	Annual
Maidden-Julian Oscillation	Eastward Propagating Disturbances in Tropics	Intra-Seasonal

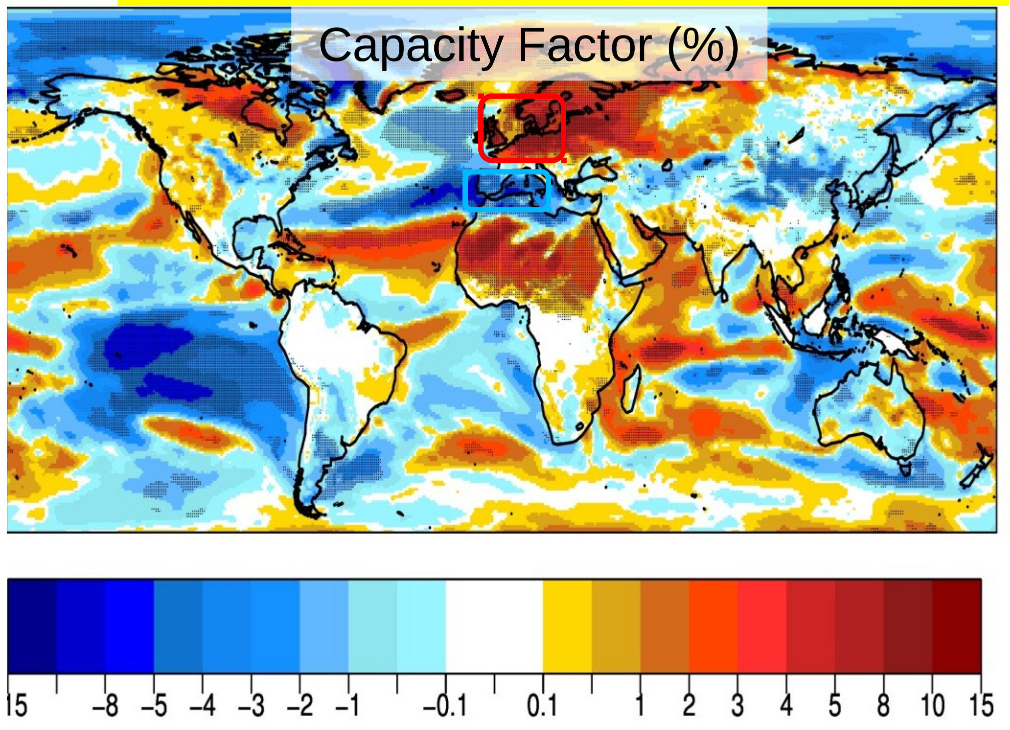
Impact of NAO on Wind Speed and Capacity Factor



Differences with NAO + and NAO - conditions

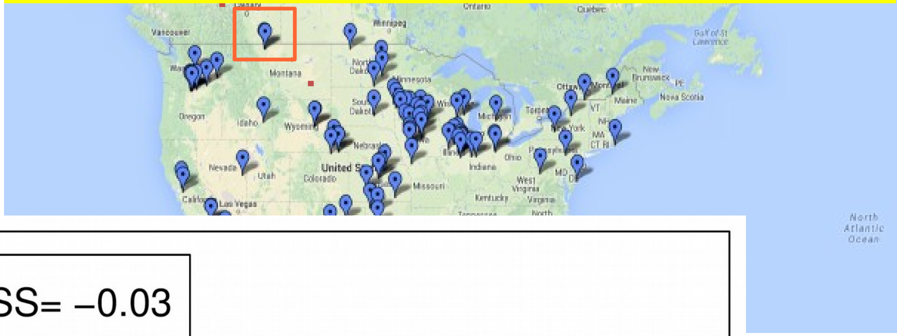
10m wind speed "observations": ERA-Interim
Boreal winter season period 1981-2012



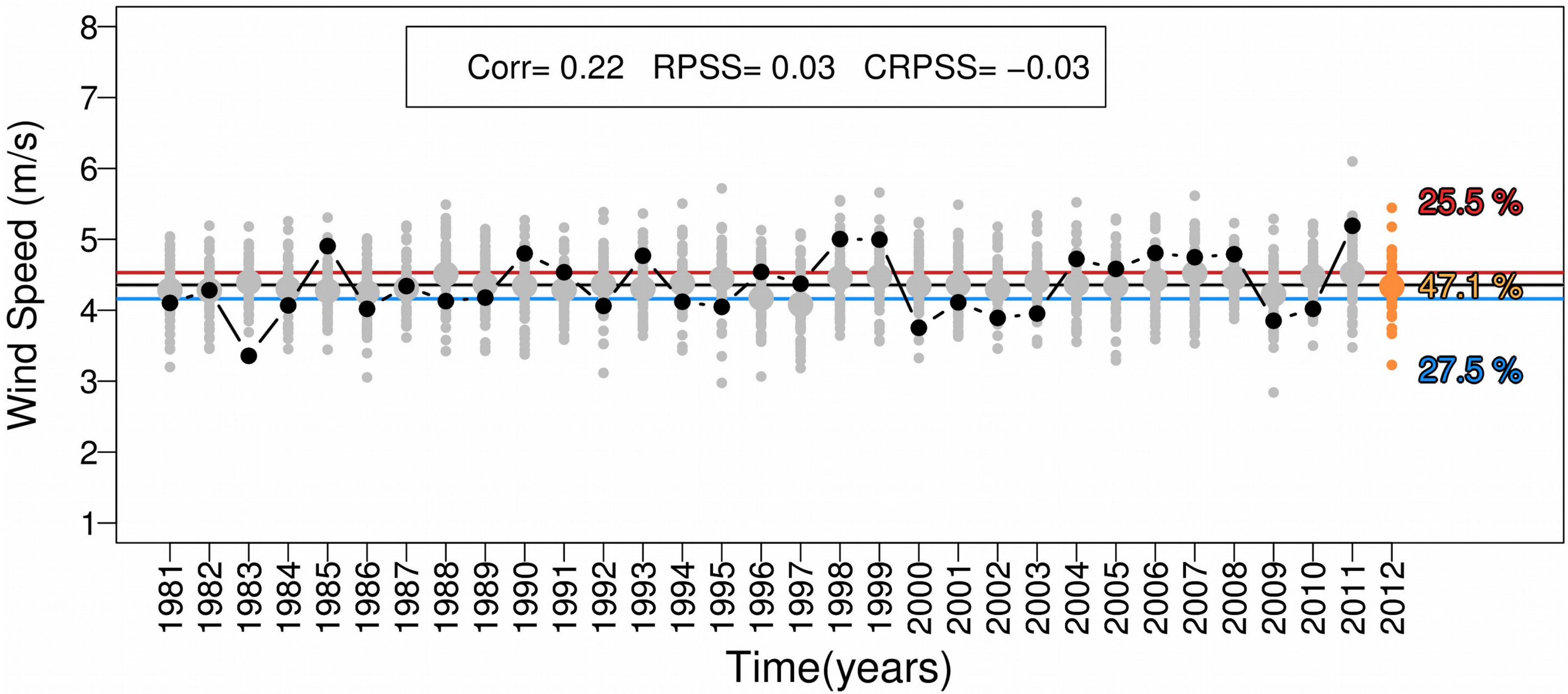


Wind Speed Forecast

Climate model:ECMWF S4
10m wind speed “observations”: ERA-Interim
Winter season forecast: 1 month lead time



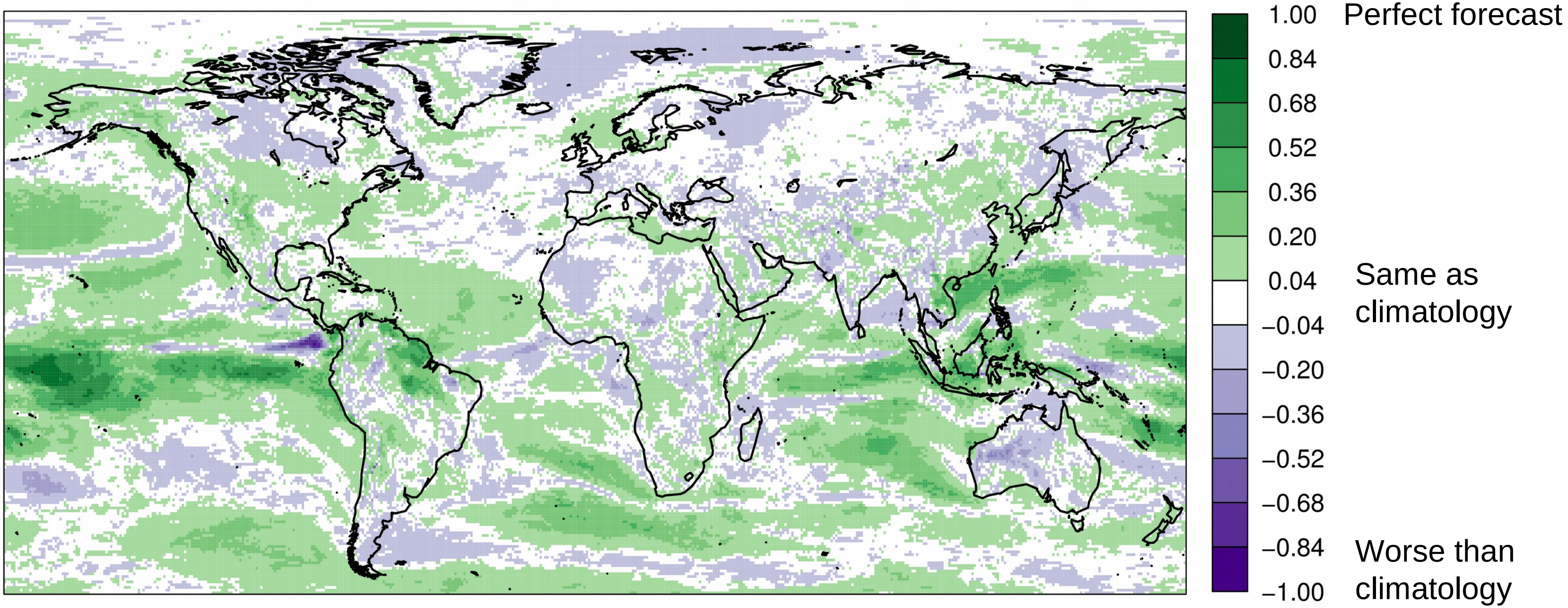
Simple bias correction



Wind Speed Forecast Validation

Climate model:ECMWF S4
“Observations”: ERA-Interim, past 30 years
Winter season forecast: 1 month lead time

10m Wind Speed Forecast Skill



Climate Forecasting Unit

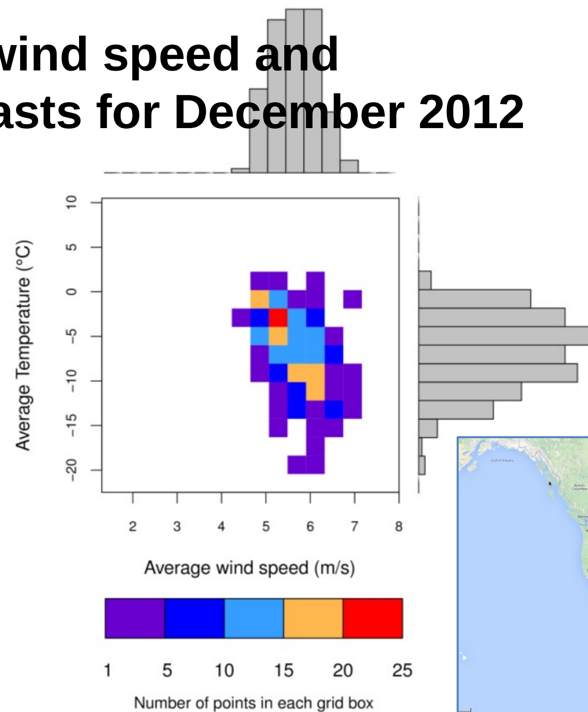
Translating Wind Forecasts into Power Capacity

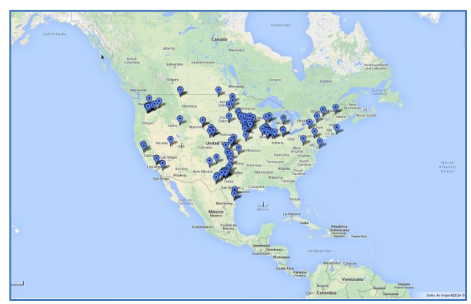
Frequency of the wind speed and temperature forecasts for December 2012

Climate model:
ECMWF S4

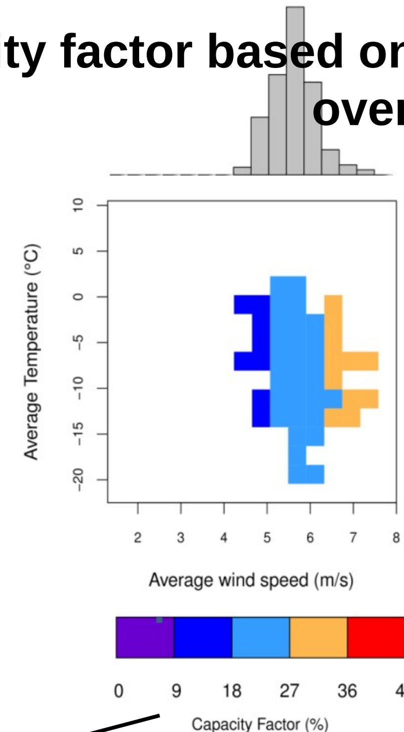
"Observations":
ERA-Interim,
past 30 years

December forecast:
1 month lead time
Simple bias correction



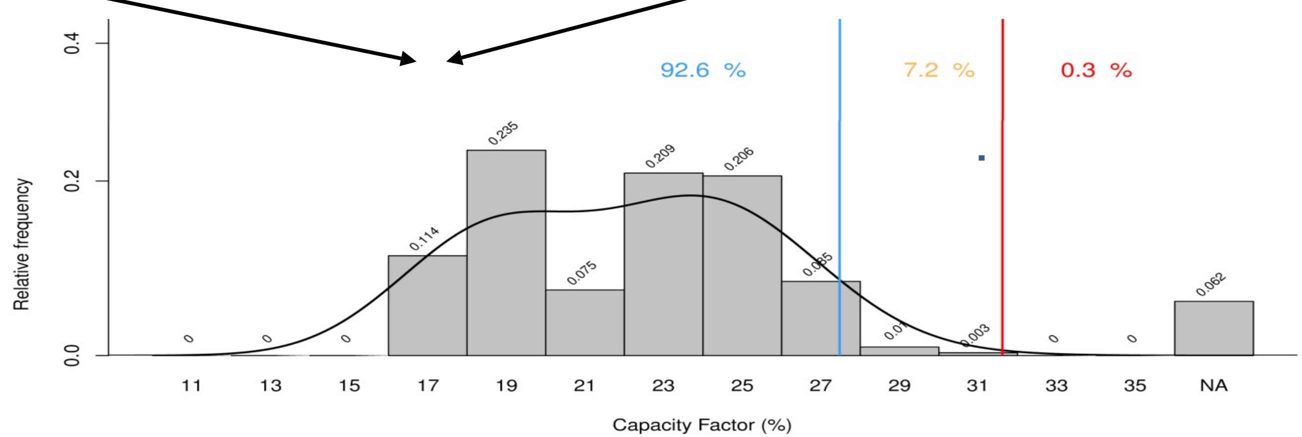


Capacity factor based on observations over past 30 years



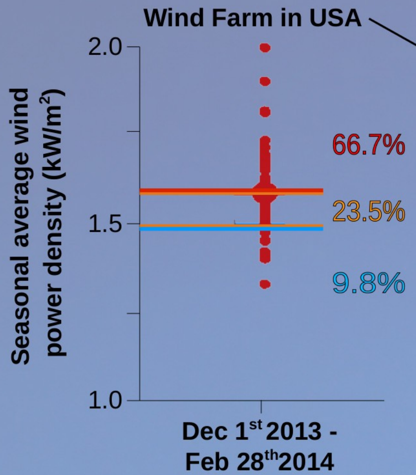
"Observations":
ERA-Interim,
past 30 years

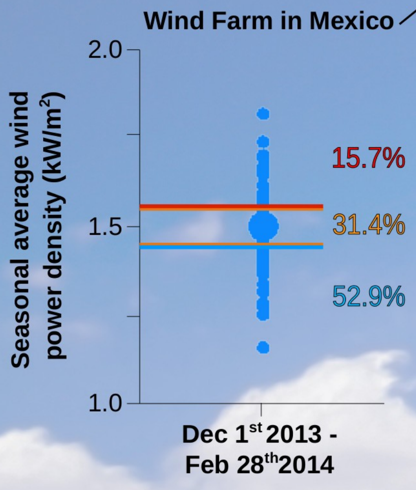
Forecast of capacity factor for December 2012

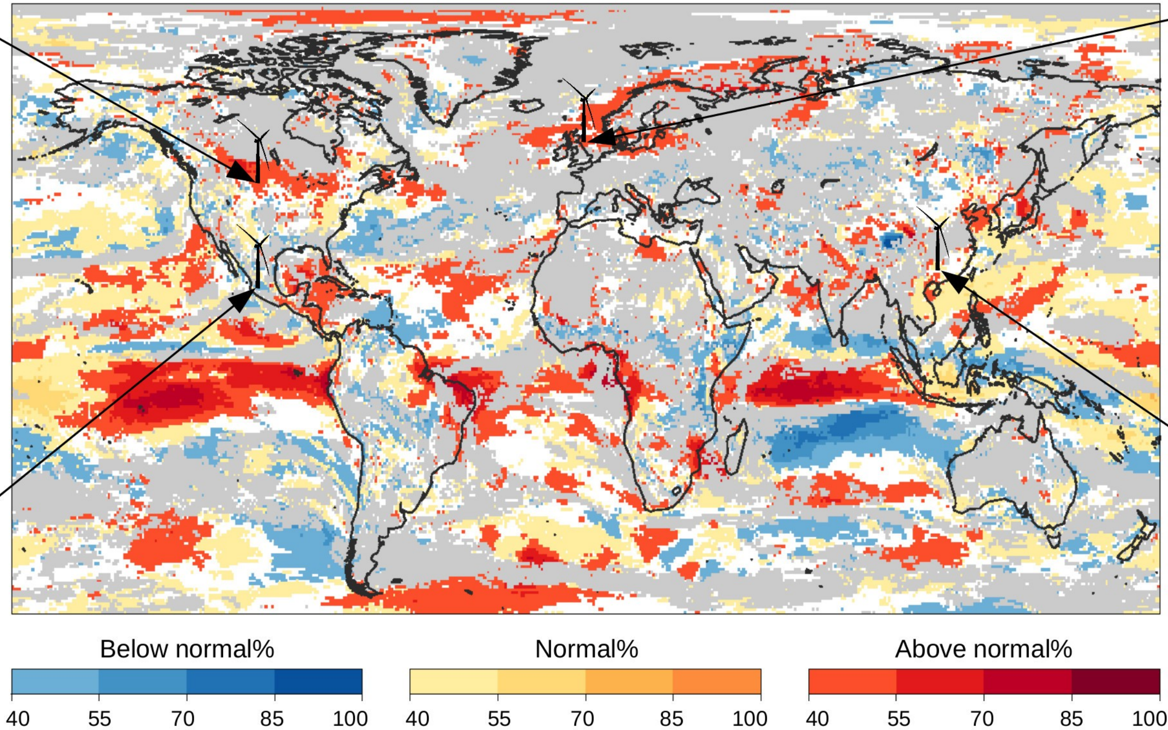


IC3 Climate Forecasting Unit

Illustrative examples of seasonal wind power predictions





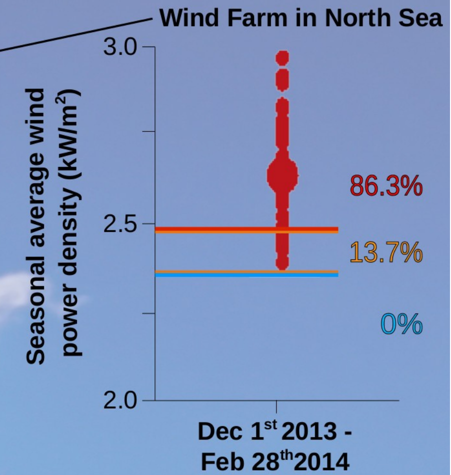


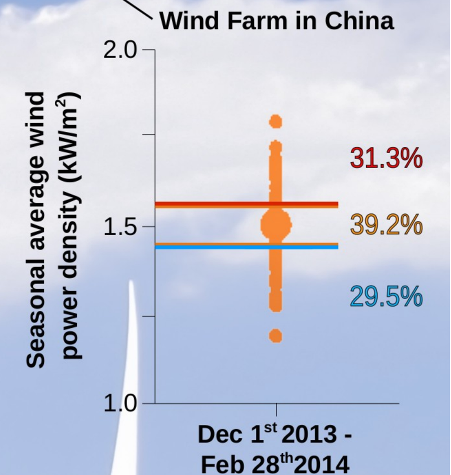
Wind power prediction for December 1st 2013 - February 28th 2014, issued on November 1st 2013.

The most likely wind power category (**below normal**, **normal** or **above normal**), and its percentage probability to occur is shown. "Normal" represents the average of the past 30 years.

White areas demonstrate where the probability is <40% and approximately equal for all three categories.

Grey areas show where the climate prediction model does not improve upon the standard and current approach, which projects past climate data into the future.





Decision Support Tools

Environment Agency — FIM Decision Support Tool — Halcrow

Date	24/06/2011	**Time**	13:29:05
Team	Anglian FF Team	**User**	Joe Bloggs

Site/Community Colne Barrier

Load Probabilistic Forecast Result Data

Potential FIM action D2. Operate active structures as necessary (e.g. close barri

Action cost £4,000

Forecast benefit £101,144

Initial recommendation Take action

Soft factors influencing the decision include:

1. Do you want to use this event as a practice or training event or as a PR exercise? [could change
2. Is the community at risk in danger of being desensitised (i.e. too many false alarms?) [could char
3. Is this a highly sensitive location with recent flooding? [could change a 'No' into 'Yes']
4. Have there been any missed flooding events (not forecast) at this site ? [could change a 'No' into

Final action decision Close Barrier

Justification

B-C ratio is very high, softer factors considered

[1] Forecast benefit comprises monetised impact of reduction in risk to life/serious injury, social impact, residentia business/agriculture damage and infrastructure disruption.

Environment Agency — FIM Decision Support Tool — Halcrow

Probabilistic Forecast Data

	Level (mAOD)	Flood impact avoided by action (£)	Exceeding threshold?
Ensemble 1	3.297	£0	0
Ensemble 2	3.296	£0	0
Ensemble 3	3.264	£0	0
Ensemble 4	3.277	£0	0
Ensemble 5	3.317	£208,981	1
Ensemble 6	3.318	£224,816	1
Ensemble 7	3.285	£0	0
Ensemble 8	3.331	£386,912	1
Ensemble 9	3.330	£376,332	1
Ensemble 10	3.288	£0	0
Ensemble 11	3.291	£0	0
Ensemble 12	3.336	£442,730	1
Ensemble 13	3.297	£0	0
Ensemble 14	3.296	£0	0
Ensemble 15	3.264	£0	0
Ensemble 16	3.292	£0	0
Ensemble 17	3.302	£25,561	1
Ensemble 18	3.342	£513,820	1
Ensemble 19	3.292	£0	0
Ensemble 20	3.288	£0	0
Ensemble 21	3.310	£124,276	1
Ensemble 22	3.310	£124,032	1
Ensemble 23	3.272	£0	0
Ensemble 24	3.284	£0	0

Expected Action Benefit (£) £101,144

Action Level Threshold (mAOD) 3.3

Exceeding probability 38%

Halcrow Water, 2013.
UK Environment Agency.

Application of Probabilistic Forecasting in Flood Incident Management.